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6. AUTHOR(S)
Robert S. Pickart

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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Office of Naval Research
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14. ABSTRACT
In winter 1997 a broad-scale hydrographic survey of the Labrador Sea was done during the period of active convection. This was part of the ONR-sponsored Deep Convection Accelerated Research Initiative (ARI) to study the dynamics of convective overturning. We observed convection both in the interior of the Labrador Sea as well as in the western boundary current, which produced two different vintages of water. Data collected later in the spring, by another component of the ARI, suggests that the newly-formed boundary current water was quickly flushed out of the Labrador Sea. By contrast, the offshore water mass was formed within a recirculating gyre and remained largely trapped within the Labrador Sea. Convection adjacent to boundaries implies net vertical sinking of the water, hence these observations have important ramifications to the meridional overturning circulation of the North Atlantic. Finally, historical data was used to demonstrate that deep convection also occurs in the adjacent Irminger Sea, which alters our view of mid-depth ventilation in the subpolar gyre.

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a. REPORT	b. ABSTRACT	c. THIS PAGE	UL	4	Robert S. Pickart
					19b. TELEPHONE NUMBER *(include area code)* 508-289-2858

Hydrography of the Labrador Sea During Active Convection

Robert S. Pickart, Principal Investigator
Department of Physical Oceanography MS #21
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
ph: (508) 289-2858 fax: (508) 457-2181 email: rpickart@whoi.edu
web site: http://www.whoi.edu/science/PO/people/pickartgroup/index.html
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LONG-TERM GOALS

To improve our understanding of the dynamics of open-ocean convection and its parameterization in large-scale numerical models.

OBJECTIVES

The main objectives are (1) to describe the large-scale context within which convection occurs, including the water masses involved and the general circulation, and (2) to characterize the mixed-layer structure and variability, both laterally and vertically, and hence shed light on the nature of the overturning.

APPROACH

A hydrographic data set was collected in winter 1997 as part of the Deep Convection Accelerated Research Initiative (ARI). These data—together with atmospheric forcing fields (K. Moore, University of Toronto) and hydrography collected the previous fall and following spring (A. Clarke, Bedford Institute of Oceanography)—were analyzed to investigate overturning in the Labrador Sea. To investigate various larger-scale aspects of convection in the subpolar North Atlantic, a hydrographic/direct-velocity data set from the Irminger and Labrador Seas during the time period 1990–1997 was assembled. Finally, using the mid-depth circulation field measured by PALACE floats during the ARI (R. Davis, Scripps Institution of Oceanography), an advective-diffusive model was created to investigate the distribution and export of Labrador Sea Water, including the effect on this due to climatic forcing.

TASKS COMPLETED

A study describing the hydrographic conditions of the Labrador Sea during active convection is now accepted for publication (Pickart *et al.*, 2001a), using data collected during the ARI. This follows an earlier collaborative model/data study of convection near boundaries (Spall and Pickart, 2001). Results from the hydrographic cruise also appear in the World Ocean Circulation Experiment (WOCE) article of Lazier *et al.* (2001). Finally, three other papers related to the ARI have recently been submitted for publication. Pickart *et al.* (2001b) investigate convection in the nearby Irminger Sea, Straneo *et al.* (2001a) study the effects of wind on convection, and Straneo *et al.* (2001b) discuss results from the advective-diffusive model of Labrador Sea Water spreading.

RESULTS

As discussed in Pickart *et al.* (2001a), convection was observed in winter 1997 both in the interior of the Labrador Sea as well as in the western boundary current. These two geographical regions produced different vintages of Labrador Sea Water (LSW). The springtime hydrographic survey, done two months after the winter cruise, suggests that the boundary current product was quickly flushed out of the Labrador Sea. By contrast, the offshore water mass was formed within the cyclonic recirculating gyre measured by Lavender *et al.* (2000), hence it is more constrained to remain in the Labrador Sea (Figure 1). Spall and Pickart (2001) discuss the ramifications of convection in a boundary current, showing that only near a boundary (and not in the open ocean) will convection cause net vertical sinking of water and hence meridional overturning. Straneo *et al.* (2001a) investigate the impact of wind on convection in a baroclinic current, and find that wind-driven lateral buoyancy fluxes can significantly enhance the overturning in the current.

Using the historical hydrography, Pickart *et al.* (2001b) show that deep convection likely occurs in the Irminger Sea as well as in the Labrador Sea (Figure 1). This idea contradicts the modern-day notion that newly formed LSW found in the Irminger basin was advected from the Labrador Sea. Oceanographic preconditioning, cyclonic circulation, and atmospheric forcing are found to be conducive for convection in the western Irminger Sea. The advective-diffusive model of Straneo *et al.* (2001b) demonstrates that the spatial distribution and timescales of newly-convected water leaving the Labrador Sea is inconsistent with the observations in the Irminger Sea, adding further credence to the idea of local formation in the Irminger Sea.

IMPACT FOR SCIENCE

Our study has revealed that deep convection occurs in the western boundary current system of the northern subpolar gyre (in addition to the interior). This implies that net vertical sinking takes place in this region, which impacts the North Atlantic meridional overturning circulation. Boundary convection also explains the rapid ventilation observed at mid-latitudes along the western boundary. Finally, if a second area of deep convection exists in the Irminger Sea as we purport, this alters our view of mid-depth ventilation in the North Atlantic, and provides a new benchmark for modeling studies.

RELATIONSHIPS TO OTHER PROGRAMS

This study was part of the Deep Convection ARI. Related projects included drifter studies, air–sea flux and atmospheric circulation studies, and analyses of moored data.

REFERENCES and RELATED PUBLICATIONS

** = Publications Related to This Project*

Lavender, K. L., R. E. Davis, and W. B. Owens, 2000. Mid-depth recirculation observed in the interior Labrador and Irminger Seas by direct velocity measurements. *Nature*, **407**, 66–69.

*Lazier, J.R.N., R. S. Pickart, and P. B. Rhines, 2001. Deep convection in the Labrador Sea. Chapter in *Ocean Circulation and Climate.* G. Siedler and J. Church, editors; International Geophysics Series, Academic Press, in press.

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*Pickart, R. S., D. J. Torres, R. A. Clarke, 2001a. Hydrography of the Labrador Sea during active convection. *Journal of Physical Oceanography*, accepted.

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*Straneo, F., M. Kawase, and R. S. Pickart, 2001a. Effect of wind on convection in strongly and weakly baroclinic flows with application to the Labrador Sea, *Journal of Physical Oceanography*, submitted.

*Straneo, F., R.S. Pickart, and K. Lavender, 2001b. Spreading of Labrador Sea water: An advective-diffusive modeling study based on Lagrangian observations. *Deep-Sea Research*, submitted.

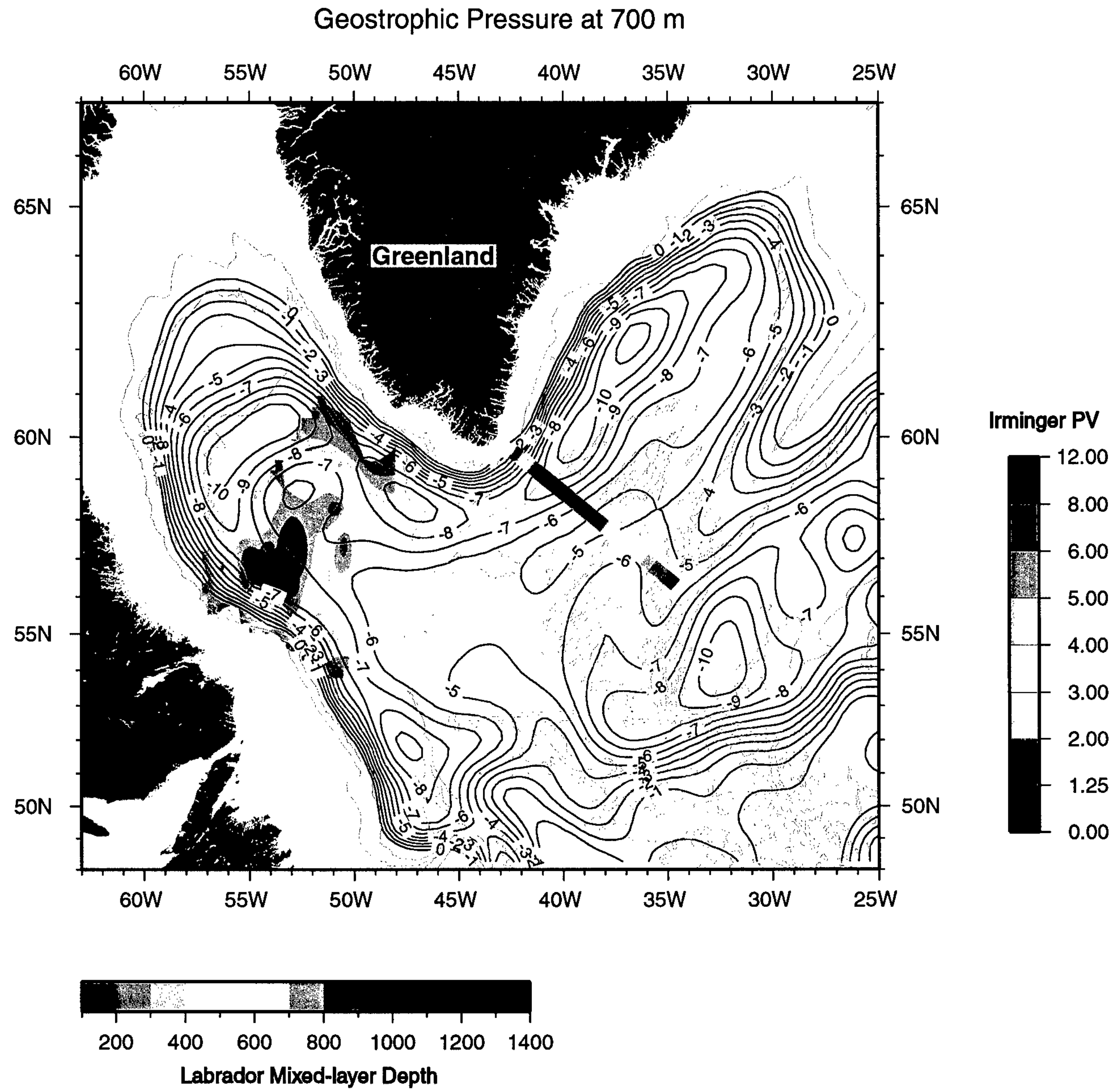

Figure 1: Mixed-layer depth in the Labrador Sea from the hydrographic cruise (lower-left color bar), overlaid on the mean mid-depth circulation field of Lavender *et al.* (2000) (contours). The deepest overturning occurred within the trough of the recirculating gyre in the western Labrador Sea. The mean distribution of planetary potential vorticity (PV), from historical data in the Irminger Sea (right color bar), shows that the most intense convection in the Irminger Sea (lowest PV) occurred within the trough of the recirculating gyre there.